

POWER SUPPLIES ON A SHOE STRING

(PART 1)

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John Case was a senior lecturer in electronics and radio communications at South Glamorgan Institute of Higher Education. He is now retired and able to devote more time to amateur radio, especially to home construction of equipment which is one of his major interests.

Power supplies, especially high current types, are expensive items to purchase. The home-constructor has often found that the cost of new parts can be almost as high as that of a ready-built equivalent commercial unit. Although the fun of building and using a piece of homebuilt equipment is present, much more satisfaction will be experienced if there is also a considerable saving in cost. The main object of this article is to show ways by which a very considerable saving in outlay can be made—costs in the region of one-tenth of that of the commercial unit can usually be possible. Experienced constructors may find these notes rather elementary, but they are written with newcomers to the art in mind.

The transformer

This is probably the most costly item of a low-voltage power supply, so much of the article will concentrate on saving as much as possible on this. For example, a transformer having a secondary that will provide 20V at 25A will cost in excess of £30. If time is not taken into account, it should be possible to modify a suitable transformer to give the above output at a cost of £3-4! It is not too difficult, and once attempted will often become standard practice for any future low-voltage/high-current units. First, a suitable sample must be found—likely sources include: old valve radio receivers and radiograms, the junk boxes of other amateurs, radio rallies and the second-hand shops. It is most important to be able to quickly and fairly accurately assess the suitability of a particular transformer, especially if buying at a rally etc, so before commencing the search a little homework is necessary.

The rating

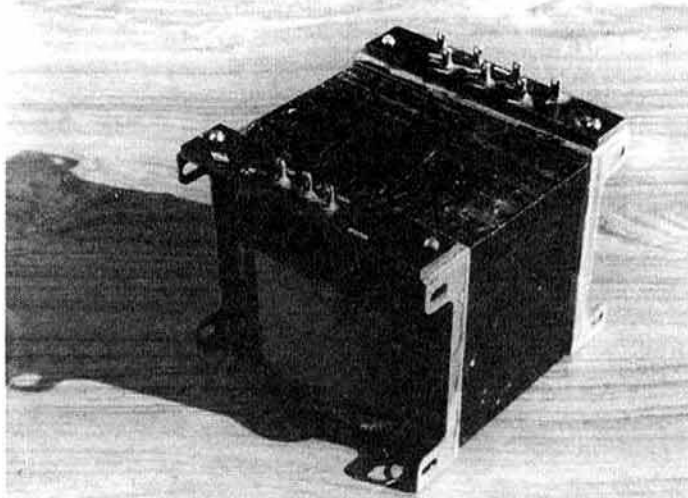
The output voltage and current must be decided, and from these figures the rating of the transformer in Volt Amperes (VA) calculated. The secondary voltage needed will be about one-and-a-half times the required dc output voltage of the power supply unit. Remember that if the input voltage is too high the excess must be dropped across the control element, causing it to get hotter than necessary, thus requiring higher power devices and bigger heat sinks. If the input voltage is too low, the voltage across the reservoir capacitor may drop below the minimum required by the stabilizer circuit during the period when the rectifiers are non-conductive. The rating is obtained by multiplying the maximum output current by the transformer secondary voltage. For example, a psu giving 10A at 14V, the transformer secondary voltage should be $14 \times 1.5 = 21V$ and the rating $21 \times 10 = 210VA$. Now a double-wound transformer, ie separate primary and secondary windings, for use on a 50Hz supply will weigh approximately 4.5lb (2.5kg) for every 100VA of its rating. By this rule the above transformer should weigh in the region of 8-10lb. This is the weight of the complete transformer—those with metal shrouds will, of course, weigh more than the more normal and, for our purpose, more useful skeleton types. If you are not very good at estimating weight, perhaps a spring balance would be useful!

A suitable type

Having found a "door stop" of the required size, examine it very carefully for the following characteristics: (a) Does it look as if it will be possible to remove the core. Avoid any that are covered in varnish or coated in thick plastic-looking material and those with toroid or C cores. (b) Can the windings be identified. Low-voltage, high-current windings (4V, 5V or 6.3V on old valve radio transformers) will be wound with thick wire 20swg (1mm) or thicker, and are normally the outside windings. HT windings, possibly labelled 250V-0-250V, or 350V-0-350V, will be in thinner wire—30swg or thereabouts. The primary, the most important one, may have a number of taps marked 0, 200V, 220V, 240V, or even -10V, 0, 200V, 220V, 240V, or it may be a simple winding with no taps. Occasionally you may come across two separate windings marked 0-120V and 0-120V, these being connected in series for 240V mains and in parallel for 120V supplies used in some parts of the world. Anyway, the primary must be identified and it must be the innermost winding on the bobbin because this is the only winding to be retained. Incidentally, the primary is almost always on the inside of the bobbin.

Test it

Let us now suppose that a suitable transformer has been found: ie the weight is about right, the core looks as if it can be removed (with difficulty) and the primary is on the inside; and, of course, the cost, if any, should be very low—after all the only use of the thing (as already mentioned) is as a door-stop—£1 or less is about right. We are in business. Before proceeding with our modification a test must be made to make certain that there are no faults on the transformer. Nothing is more upsetting than to spend a great deal of time rebuilding only to find that the thing was faulty before work commenced. Simple tests will show the presence of two possible faults: (a) Use an ohmmeter to measure the resistance between one



1007VA. A very heavy "doorstep" awaits treatment

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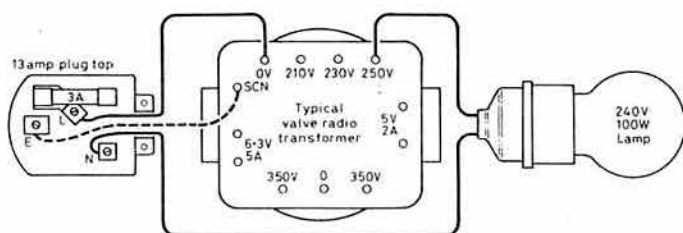


Fig 1. Testing for shorted turns

end of the primary and the core. It should be very high, more than $1M\Omega$ unless the thing has been stored in very damp conditions, in which case the resistance should rise when it is dried out. (b) This test will indicate the presence of one or more shorted turns in the windings; if there are, then it is pointless to proceed—take the transformer back or put it down to bad luck. Cut off or desolder all the old leads from terminal tags or, if there are no tags, insulate the ends of all leads except the 0 and 240V primary leads. Now connect the primary to a mains plug, with a 3A fuse, with a mains type bayonet cap lampholder in series as in Fig 1.

Fit a 100W mains lamp into the holder. Make sure that you observe all the normal safety procedures, then plug into the mains and switch on. If the lamp lights brightly, check the connections and make sure that the winding used is all of the primary. Do not proceed if the lamp lights brightly—either the primary is short-circuit or you have used a low-voltage winding! If the lamp lights very dimly or not at all but gets hot, leave the circuit switched on and feel the core every 10min or so for about half-an-hour. If at the end of this time the core is only slightly warmer than at the beginning of the test, the primary is almost certainly OK. If you want to be absolutely sure, repeat the test with the lamp replaced by a direct connection. Before switching on make sure that the fuse in the plug top is not rated at more than 3A; 1A or 2A would be better. Switch on and leave for a further half-hour. Do not use the transformer if there is a significant temperature rise.

Anyone having access to a variac transformer should be able to devise a similar test by using a low input voltage and progressively increasing it to 240V while monitoring the core temperature. Whichever method you use, be very careful to insulate mains connections and keep clear of terminal tags. Old radio transformers may have 700V or more across the ht secondary. No problem as long as great care is taken while the mains are connected. Later these windings will be removed. Once satisfied that there is no great rise in temperature, switch off and remove the mains connecting wires.

Getting the core out

Remove any fixing bolts or studs and clamps, being careful to avoid damage to the windings at this stage. The next bit is the most difficult, and if you can succeed here you are almost there. Cores are made up from either Ts and Us or Es and Is as shown in Fig 2. These laminations, or laminations as they are sometimes called, are thin sheets of high permeability iron insulated on one side, interleaved alternately to make up a core with excellent magnetic properties but a poor electrical conductor from one side of the core to the other to prevent eddy currents flowing in the core. They are tightly packed. The Us or Is on the outside of the core are easy to remove; an old kitchen knife comes in handy for this, but the first E or T must be carefully driven out. A thin piece of steel such as a short section of an old steel rule may be used as a drift. Stand the transformer on the edge of a stout bench or thick piece of wood with the edge of the core just clear of the edge, then with the drift against the centre of the T or E, give several blows with a light hammer (see Fig 3). It will be almost impossible to get the first or even the second lamina out without damaging it or them, but don't worry about this, it is almost impossible to get them all back anyway. When removing Es the outer legs should be released, again using the knife.

If you can manage to drive one of the end laminations out just a little so that it can be gripped in the jaws of a vice, a bit of brute force will probably do the rest (see Fig 4). If there is no vice available, try mole grips or a large

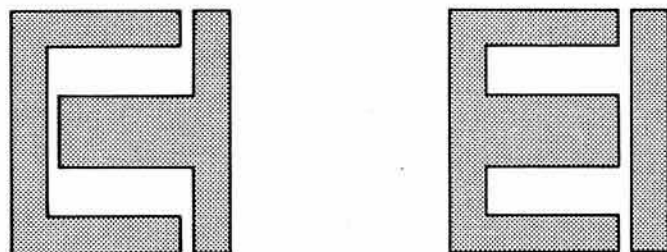


Fig 2. Typical core sections

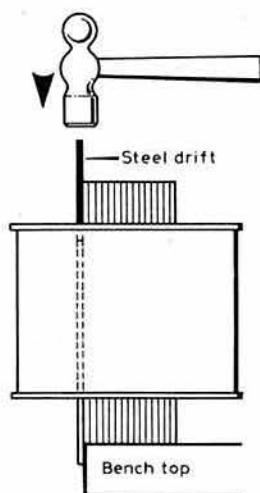


Fig 3. Using a thin drift to move the first lamina

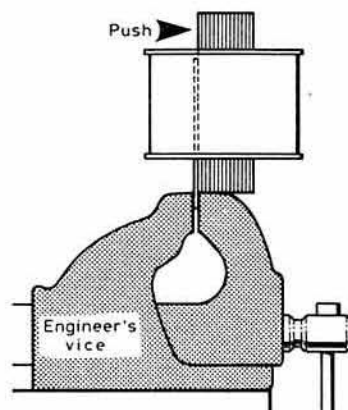
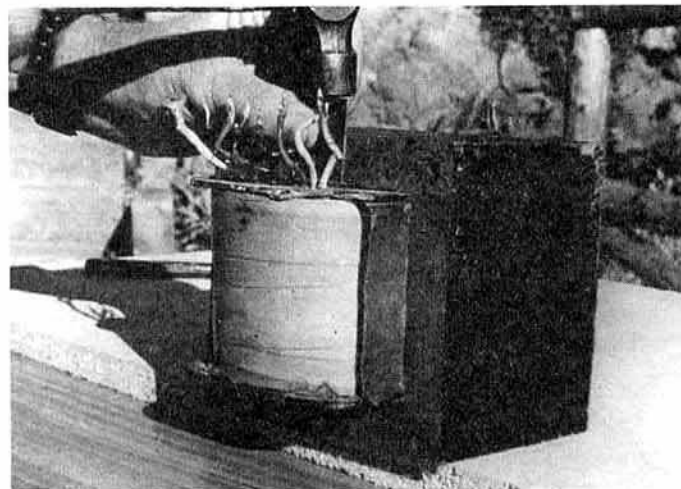


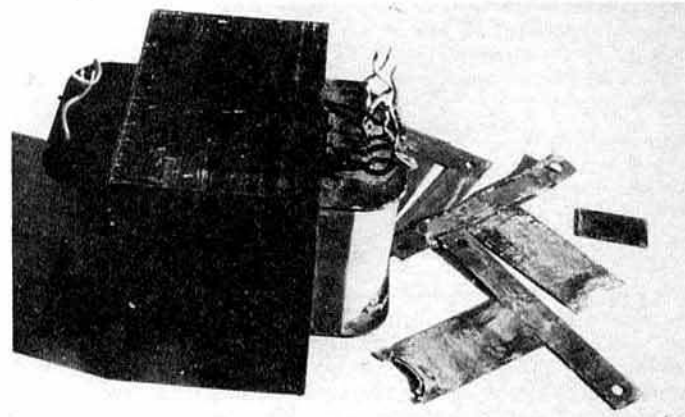
Fig 4. Grip the end of the lamina in the vice

pair of snub-nosed pliers. Having cleared one or two laminations (by force), it will be necessary to break the others apart as they are usually stuck together by paint or varnish or even rust! The kitchen knife is again useful, together with the judicious use of a light hammer. Separate all the laminations even if they come out in pairs or more, and stack them individually as Ts, Us etc.

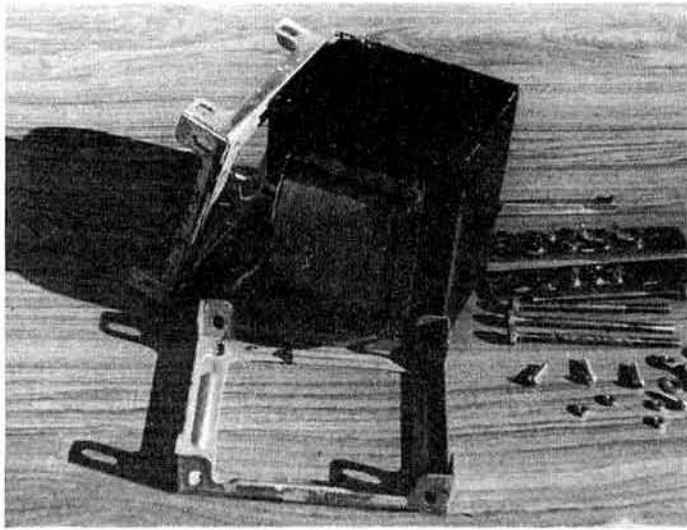


The first lamina moves under protest

You should now have a bobbin of wire and insulation, and the next task is to remove all of the windings except the primary. Any method of removing the wire may be adopted, such as unwinding—tedious and generally messy. There is rarely any point in trying to save the wire removed as it will be varnished and have bits of paper, used to separate layers and windings, sticking to it. I normally unwind thicker windings, almost always



Damaged but out!



Transformer stripped of end plates and terminal posts

on the outside of the bobbin, and then use a hacksaw to saw *almost* down to the primary insulation. Great care is necessary to ensure that the primary is not damaged in any way.

Some transformers may have an electrostatic screen between primary and secondaries, and if this is the case with your sample it can be retained, as it will help to prevent the passage of rf through the transformer back into the mains and so reduce the chances of tvf when the psu is used with an ssb transmitter. The screen normally takes the form of a strip of brass foil, almost as wide as the bobbin, wrapped around the outside of the primary insulation but with insulating paper interleaved, so that the ends of the loop do not short together and so form a disastrous shorted turn. Make sure that the connection to the screen is still intact, as this must be connected to chassis for the rf shielding to be effective.

Now a good insulating layer must be put on over the top of the primary, and the screen if present. This can take the form of strips of brown paper having the same width as the bobbin. The paper should be covered with melted paraffin wax (candle grease) which will hold the paper in position as well as improving the insulating property of the paper. If waxed paper from a large paper dielectric capacitor is available, it is ideal for this purpose. About four layers of waxed paper should be satisfactory.

The new winding

The next step is to determine the number of turns required for the new secondary. A number of ways are possible but the following will always work. Wind a few turns of "hook-up" wire around the bobbin, counting the number very carefully. Ten or 12 turns is normally quite sufficient. Twist the ends of the wire together to hold the winding in place and remove about 5mm of insulation from each end. Now push most of the core back into the bobbin. There is no need to interleave the core as it was originally for this part of the exercise, pack 10 or more Ts one way, then the same number in the opposite direction, continuing until almost all of the core is put back, with packs of Us filling in the gaps. If the core is made up from Es and Is there is no need to put in the Is at all. Connect an ac voltmeter (10V range) between the bared ends of the hook-up wire, and connect the 240V primary to the mains via a 1A fuse, again observing all of the safety measures normally used with supply mains. Carefully read the voltage indicated by the voltmeter. Switch off and disconnect.

Calculate the number of turns required on the new secondary from the simple formula:

$$\text{Turns required} = \frac{\text{No of test turns} \times \text{voltage required}}{\text{Measured voltage}}$$

For example, with 10 test turns a voltage of 2.5V occurs across the test winding, and a 21V winding is required:

$$\text{Turns required} = \frac{10 \times 21}{2.5} = 84 \text{ turns}$$

Incidentally "Turns required/measured voltage" gives what is known as the turns/volt, and just for fun the number of turns in the primary winding can be calculated by the same method. In our example the primary would have $10/2.5 \times 240 = 960$ turns. The high number of turns required on the primary is one reason why we have made use of a ready-made winding. Another point worth remembering is that the turns/volt gets lower as the transformer gets bigger. As a rough guide, a core with a cross-sectional area

(through the bobbin) of 1in^2 , would have about 8t/V . The figure is in inverse proportion to the area, ie a core area of 2in^2 gives 4t/V (our example). The transformer used in the photographs has an area of $4 \times 2\text{in} = 8\text{in}^2$, and will therefore require only 1t/V or less. The actual value of t/V will be measured as previously described—if I can get the core out!

Choosing the wire gauge

There are a number of ways of deciding what gauge of wire to use, the easiest being the use of wire tables if you have access to some. Not only will they give the current-carrying capacity but also the amount of space that will be required for a given number of turns. Note that the current rating must be for transformer use; open wires such as house wiring cables can carry much more current because of the better heat dissipation whereas in a transformer there is a long length of wire in a very small space. See Table 1.

Alternatively the cross-sectional area of the required wire may be calculated by using a current density of about $1,500\text{A/in}^2$ or 2.5A/mm^2 . For example, suppose that we need wire that will carry 15A, then the cross-sectional area must be: $15/1,500 = 0.01\text{in}^2$ or $15/2.5 = 6\text{mm}^2$. Then with the help of a calculator or any budding mathematician we can calculate the diameter of the wire required:

$$\text{Diameter} = 2 \times \sqrt{\frac{A}{\pi}} = 2 \times \sqrt{\frac{6}{3.14}} = 2.75\text{mm}$$

If you have a micrometer, then a good approximation to the capacity can be obtained by squaring the diameter of the wire, expressed in mils ($1/1,000\text{in}$), this gives what is known as the area in "circular mils". A circular mil will carry 1mA, therefore circular mils = milliamperes.

Is there enough winding space

Having decided on the correct gauge of wire, it is necessary to ensure that the required number of turns will fit into the space left by the windings that have been removed. Place a T or an E into the bobbin so as to locate the position of the core and then measure the space in inches (see Fig 5). $A \times B$ gives the winding space in square inches, and reference to Table 1 will enable the space required to be ascertained. For example, using the figures previously given, ie 10A at 21V, the new winding would need 84 turns of 13swg. In Table 1 13swg gives 12A and 108 t/in^2 so that a winding space of about 0.75in^2 would be needed. In practice it is difficult to achieve the turns density given by the wire tables, so a generous allowance should be made and for 84 turns rather more than 1in^2 would be about right. If the space available is less than indicated it would be necessary to reduce the wire gauge, in this case to 14swg or 2mm. In fact this would be satisfactory, as the rating given is 9A.

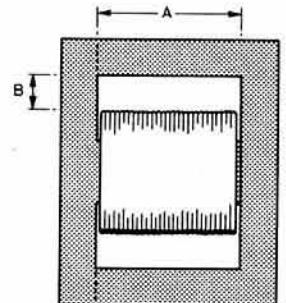


Fig 5. Assessing the available winding space

Table 1. Winding and current capacity details for different wire gauges

Diameter mm	Diameter mils	Gauge (swg)	Turns/in	Turns/ in^2 of winding space	Approx current (A)
1	39	19	23	550	1.5
1.25	49	18	19	388	2.5
—	56	17	17	287	3.5
1.5	59	—	15.7	230	4.0
—	64	16	14.5	219	5.0
1.75	67	—	13.9	190	6.0
—	72	15	13.25	175	7.0
2.0	80	14	11.9	141	9.0
—	92	13	10.42	108	12.0
2.5	98	—	9.8	96	13.5
—	104	12	9.25	85	15.0
3.0	118	11	8.33	69	20.0
—	128	10	7.6	58	25.0

Both metric and imperial sizes are given, and where the dimension is almost the same only one entry is shown. One mil = $1/1,000\text{in}$.

TO BE CONTINUED

POWER SUPPLIES ON A SHOE STRING

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(PART 2)

Putting on the new winding

The method of putting on the winding will depend on the type of construction used in the original manufacture. If a paxolin bobbin has been used there will be no great problem in holding the turns in place as they will be confined by the cheeks of the bobbin, but if the winding is open, ie no bobbin as such, then a special technique to be described later must be used. In either case a simple mandrel will be necessary to enable the thick wire to be wound on in even layers. Note it is most important that turns should lie flat, if one turn crosses over another it is almost certain to lead to a shorted turn and the eventual breakdown of the transformer.

The mandrel can be a block of wood that will just fit into the centre of, and is slightly longer than, the bobbin. The block is drilled through the centre using a 0.25in or 0.5in drill bit, depending on the size of the transformer. A piece of steel rod or a long bolt is passed through the hole and is then clamped into the jaws of a vice. This enables the bobbin to be turned and leaves both hands relatively free for the other tasks.

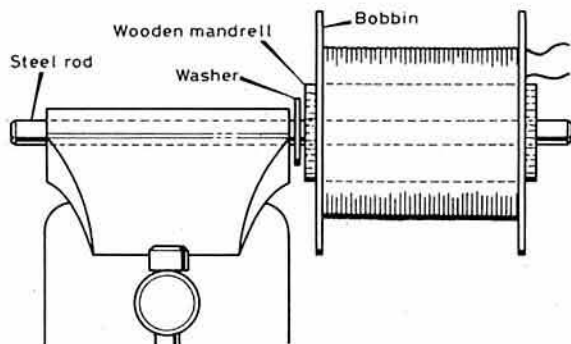


Fig 6. Method of holding the bobbin during winding

Pass one end of the new wire, covered with sleeving, through a convenient hole in the side of the bobbin, making sure that the wire will not be in the way of the core when it is re-assembled. If there is a terminal tag strip then only a short end, long enough to reach the appropriate tag, will be needed, if there is no tag strip then leave a longer end so that it will reach the rectifier bridge in the psu. The next job should be done when there is little chance of interruption, as it is necessary to count accurately the number of turns put on. Keep the turns tight and even, but avoid allowing the new wires to slip down between the existing primary and the bobbin sides. Continue winding evenly until the full number of turns is wound on, then pass the end of the wire, again covered in sleeving, out through a convenient hole in the bobbin side.

If the bobbin is flimsy it would be a good idea to adopt the technique that must be used when there is no bobbin. This process is a bit more fiddly but is not so difficult in practice as the following description might suggest. Before starting, cut 12 lengths of 0.5in linen tape, each about 6in long; two or three lengths of adhesive tape, about 1.5 times as long as the circumference of the bobbin, to wrap around the winding if you are interrupted so that the turns do not spring loose; and have a pencil and paper handy so that the turns count can be jotted down. Fix four pieces of linen tape to the bobbin with paraffin wax so that one end is about level with the edge remote from the edge of the bobbin, wind the first turn over the top of the four tapes, then as the next turn is put on, fold each tape back

to the opposite end and wind about five or six turns over the top of both layers of tape. Pull firmly on each of the long ends so as to lock the first turn firmly in position against the subsequent turns. Continue winding until about 0.25in away from the edge of the bobbin, insert a strip of insulation paper and wind the next turn over it. Bring the next turn up on top of the last, double the tapes back over and again wind over the top of them. This time working back towards the beginning.

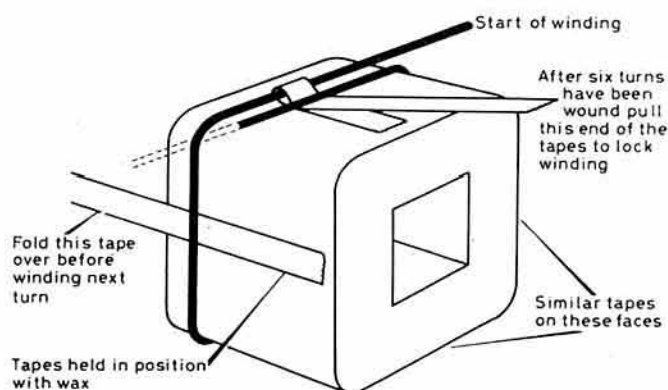
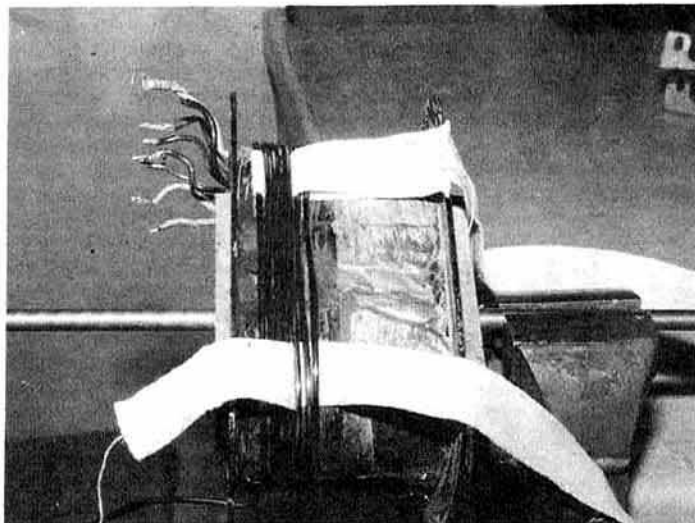


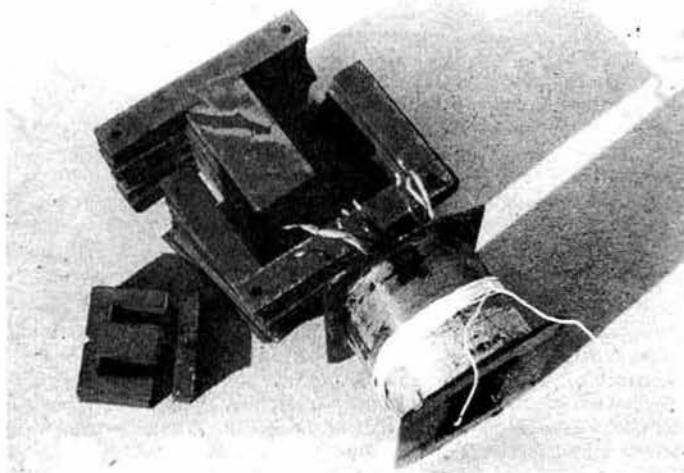
Fig 7. Using tapes to hold the new winding in position

Repeat the process, locking the turns at the end of each layer, as already described, and inserting a layer of insulation between layers. Continue until five or six turns remain to be put on, then take some more tapes, double them and wind all but the last turn over them so that the closed loop is at the end. Pass the end of the wire through the loops, pulling the end of the tapes so as to hold the last turn and the rest of the winding in position. Cut off the ends of the tapes, then cover the winding with several layers of suitable insulation material. A coating of wax or, if preferred, polyurethane varnish over each layer as the winding progresses will help to keep the damp out.



Using tapes to hold the turns in place

*2 Abbey Cose, Tyrhiw, Taffswell, Mid-Glamorgan



Ten test turns in position

Re-assembly

The core should now be put back, but this time the laminae must be put in singly and fully interleaved. Also try to keep the laminae all the same direction, ie with the insulated sides all facing the same way. If you wish to put back any pieces that were damaged during removal, it is a good idea to put them in the middle of the stack rather than leave them to last. When almost all are in position the space will appear to be too little to accept the remaining pieces. The blade of a set-square or similar piece of metal can be used to compress the laminae, and it should be possible to insert all but one or two pieces. Stand the transformer on one side and, with a piece of wood and a hammer, tap the laminae on all sides to get them fully in position. Complete the outer layers (both sides) with Ts or Is and then reassemble the clamps and fasten the bolts very tightly. If there was a tag strip, connect the ends of the windings to convenient points. The transformer is now complete and should be tested in the same way as the original. The secondary voltage can be checked and, if left switched on, there should be no significant increase in core temperature after 30min or so.

Rectifiers

Radio rallies can again help with these. I bought a bag of assorted diodes for 50p about three years ago. This proved to be a very good buy; you only need to have one good power diode to be out in front, but in fact there were very few duds. There were over 200 pieces in the bag, ranging from switching diodes, 1N4148, to large power diodes, some of which have been tested up to 25A. The main snag with the power devices is that they are stud mounting and were without nuts, which should be 10/32 UNF. The studmounting types come in stud-anode and stud-cathode, and both types were in the bag.

These allow bridge rectifiers to be made up with the use of two heatsinks (see Fig 8). If the power diodes are unmarked (as most of mine were) don't let this put you off, as it is a relatively easy matter to find out all you need to know with some simple tests. First check the polarity using an ohmmeter. Remember that with an analogue type instrument (AVO8 etc), the red lead

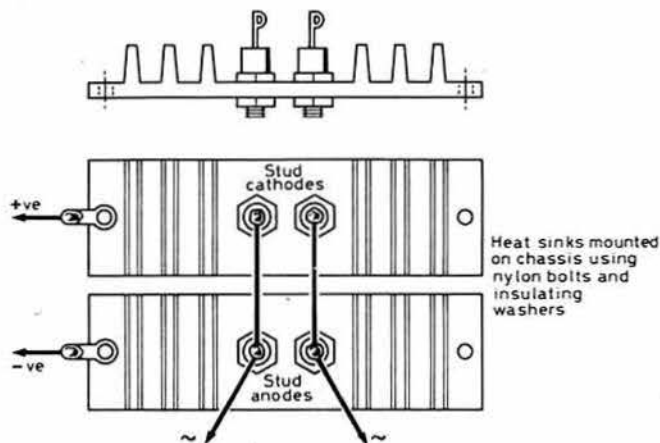


Fig 8. A bridge rectifier using discrete diode

will be negatively polarized when being used to measure resistance. A good diode should indicate about 1,000Ω in the forward direction and in excess of 1MΩ in reverse. Next check the current rating. Mount the rectifier on a heatsink to delay the rise in temperature while the test is being made. Borrow a low-value, high-current slider-type variable resistor. Connect the rectifier to the circuit shown in Fig 9. Start with the variable resistor at maximum; the current indicated by the ammeter should be less than 1A. After a few minutes feel the diode—take care, it might be very hot! If cool, reduce the value of R to increase the current to 2A, leave a few minutes and again test the temperature of the diode. Continue reducing R and checking temperature. If the required current is reached, leave switched on for 10min or so and if at the end of this time the diode is just about touchable, it should be OK. By this time the heatsink will also be getting hot unless you have used a very big one.

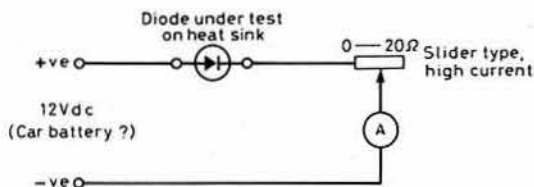


Fig 9. Circuit used for testing the current rating of diodes

If you are using the diodes in a bridge circuit or a full-wave circuit, then the current that each diode must be able to pass is only half the total output of the psu. The only other thing you need to know is the voltage (piv). If the rectifier is a bridge circuit, then the diodes must be able to withstand 1.5 times the rms input voltage, but in a full-wave or half-wave circuit the diodes must be able to stand up to three times the rms input. This is because the diode sees the peak input voltage plus the charge in the reservoir capacitor, which in the "off load" condition will be equal to the peak input. In a bridge circuit there are always two diodes in series, so that each diode sees only peak volts. To be quite safe, a wide margin of safety is advised as transients in the mains supply may increase the applied voltage to well above the expected value. It is suggested that the calculated value for piv be increased by a factor of four times. To check the piv you will need to have the use of a variable-voltage psu with a maximum voltage of about 20 per cent higher than the piv needed, eg if the input voltage (off load) to the rectifier is 22V then the peak will be 33V, and the required piv $33 \times 4 = 132V$. If the diodes are to be used in bridge then about 150V would be needed for the following test (Fig 10 shows the test circuit).

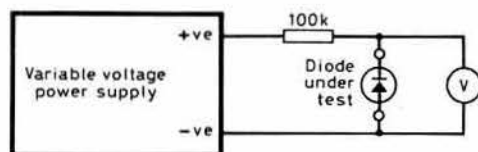


Fig 10. Circuit for testing the peak inverse voltage (piv)

Increase the voltage of the psu while watching the reading on the voltmeter. It should increase and have about the same value as the output of the psu. If the reading of the voltmeter reaches 150V all is well, but if it stops rising at 100V then the piv is 100V. A value as low as this is most unusual, and with a 22V input to a bridge rectifier there would be little danger of breakdown occurring even if the above test was not made. The simple test described can always be used to find the piv of any diode. The voltage across the diode stops rising when the diode becomes conductive in the reverse direction, but damage to the diode is prevented by the high-value series resistor. Of course, if the diode under test has a very high piv then the

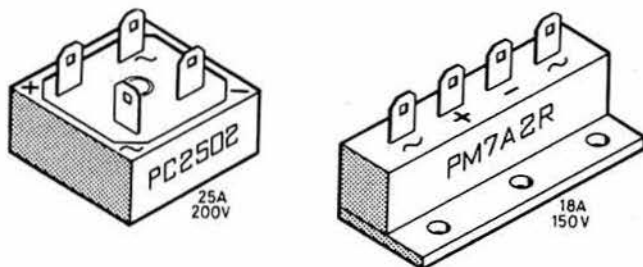


Fig 11. Some types of bridge rectifiers to look for at rallies

"breakover" condition may not be reached when the output voltage of the psu has reached its maximum, but that does not matter as long as that voltage is higher than the value required.

Although not as common, it is sometimes possible to find high current bridge rectifiers of the types shown in Fig 11 at some radio rallies. They are usually sold as being 18A, 25A or 35A, but if no rating is quoted be careful, as they are rather difficult to test. They are also dearer than single diodes. Numbers printed on the side that contain figures like 25 or 35 often, but not always, indicate the rating.

Reservoir capacitors

Again, these items can be very expensive if bought at normal retail prices, but radio rallies can usually be relied upon to provide a fairly low-cost item. When choosing a reservoir capacitor the most important thing is to make sure that it has a high ripple capacity. This must be at least as high as the current output of the finished psu. Sometimes the ripple capacity is marked on the unit together with capacitance and working voltage, but if it is not then a simple rule is to look at the terminals—if they are screw type then the ripple capacity is high and the capacitor should be satisfactory.

If the polarity is not marked, it can easily be found by means of an ohmmeter of the analogue type. When connected one way the needle will move almost to 0Ω and then climb back towards infinity. After 30s or so note the resistance reading. Now reverse the meter and repeat the test. A similar result will be obtained, but in one case the resistance reached after 30s will be much higher than in the other. The higher resistance indicates that the meter is correctly connected—again remember that the polarity of the meter is reversed, ie the red lead is negative.

Next, the capacitance must be decided. If a voltage stabilizer is to be used, a useful rule of thumb is: 2,000μF for each ampere of output current. If a smaller value is used there is a very good chance that the voltage across the capacitor will drop below the minimum value required for the input to the stabilizer while the rectifiers are non-conductive and ripple will appear on the output of the psu.

Finally, the working voltage must be higher than 1.5 times the rms output voltage of the mains transformer. So for our original example—a 210VA transformer giving 21V at 10A—the reservoir capacitor would need to be $10 \times 2,000 = 20,000\mu\text{F}$ with a ripple capacity of 10A and a working voltage of at least $21 \times 1.5 = 31.5\text{V}$, a practical value being 40V. The retail price of such a unit could well be £9-£10, but at a rally can often be found at about £1-£2. Capacitances and working voltages mentioned above are minimum, and no harm will occur if they are bigger than necessary.

With transformer, rectifier and reservoir capacitor, the basic unit can be set up. A common mistake at this stage is to use heavy-gauge wire from transformer to rectifier and from rectifier to stabilizer, and then to use a lighter gauge wire to connect the reservoir capacitor. This wire must be of equal current rating as the rest, because the leads to the capacitor carry the charge and discharge currents, and resistance in the leads would reduce the effectiveness of the capacitor. In fact the ripple capacity is very largely decided by the size of the internal wires connecting the foils to the terminals of the capacitor.

Stabilizers

Much has been written on this topic, so only simple circuits will be considered here. One of the simplest methods of obtaining a stable voltage at a high current is to make use of a voltage stabilizer chip which will give a stable output voltage at a relatively low current, and to follow with a current amplifier which can be almost any high-current, high-power transistor. The basic circuit is shown in Fig 12.

If the maximum current output of the stabilizer chip is 0.5A, it will be more than enough to drive a 2N3055 to its maximum rating. The voltage at the emitter will be about 0.6V lower than the output of the stabilizer, which should be adjusted to about 14.1V in order to give a 13.5V output. If the voltage across the reservoir capacitor is 25V then the 2N3055 must

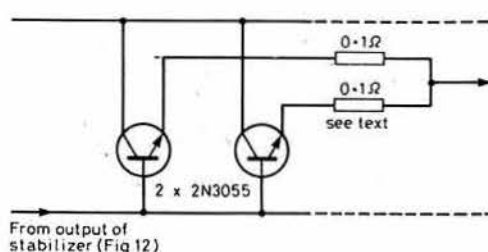


Fig 13. Using power transistors in parallel to increase output current

drop $25 - 13.5 = 11.5\text{V}$. If the output current rises to 10A then the power dissipation of the transistor $11.5 \times 10 = 115\text{W}$ which is in fact its maximum rating. Even with a very good heatsink, early failure is likely. It would be much better to have two 2N3055 transistors in parallel so that the dissipation is shared. Unfortunately transistors cannot be operated in parallel without modification; they might oscillate at some indeterminate frequency but, more important, one transistor would pass more current than the other and so get hotter. Because transistors have a negative temperature co-efficient, the unbalance will get worse as the conductivity of the hotter transistor increases, resulting in the failure of one transistor followed rapidly by failure of the second.

To prevent this happening, a ballast resistor of about 0.1Ω is connected in series with the emitter of each transistor. The only problem is finding suitable resistors—0.1Ω at 2.5W. Nichrome wire from an old electric fire element can be used but is difficult to solder. Two strands, 4cm long, twisted together and crimped into a small soldering tag at each end will make a resistor that will be able to pass 5A without getting too hot. The exact value of the resistor is not too important as long as the two are near enough equal. Connect as shown in Fig 13. The main problem with this simple type of stabilizer circuit is the difficulty of including short-circuit protection and, unless you are very lucky, a brief short-circuit across the output of the psu will result in the loss of both 2N3055s if more than one is used. Incidentally this transistor was chosen because it is readily available at very low cost.

There are better transistors available, such as the 2N3772/3, both of which will dissipate 150W and can pass currents of up to 20A; but they are much more difficult to obtain and are very much more expensive—up to £3 on the normal retail market. The recommended stabilizer chip is the 123 or 723 ic which will allow current limit to be easily incorporated. The maximum output of these ics is only 150mA and an extra amplifier will be needed to drive the 2N3055s. A complete practical circuit is shown in Fig 14.

Either L123 or L723 may be used, as they are electrically the same but in different packages. I prefer the L723 simply because it is generally easier to obtain at rallies etc, and is easier to fit into Veroboard or a pcb because of the 14-pin dip encapsulation. The pin connections of both types are shown in Fig 15. Note that the diagrams show the pin connections looking at the top of the ic. The voltage sampled by the resistors R4 and R5 and RV2 determines the voltage at Vout of IC1. This in turn fixes the voltage output of the psu. RV1 enables this voltage to be varied within narrow limits, about 12-14V. The top of R4 may be brought out of the psu by means of a separate terminal. For normal use this will be linked directly to the positive output terminal, but if the leads to the linear amplifier or other load are long there will be a voltage drop across these long leads; this voltage drop will vary according to the current being drawn, so spoiling the stability of the supply.

To maintain a constant voltage at the load, the sense terminal should be connected to the positive rail at the point of entry to the linear etc. This will produce a slightly strange phenomena if the psu voltage is monitored by a meter, either internal or connected to the terminals of the psu. The voltage will rise as the load current is increased. This is because the output voltage

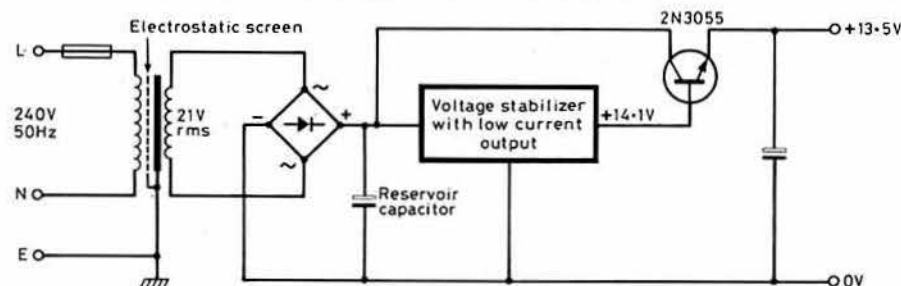
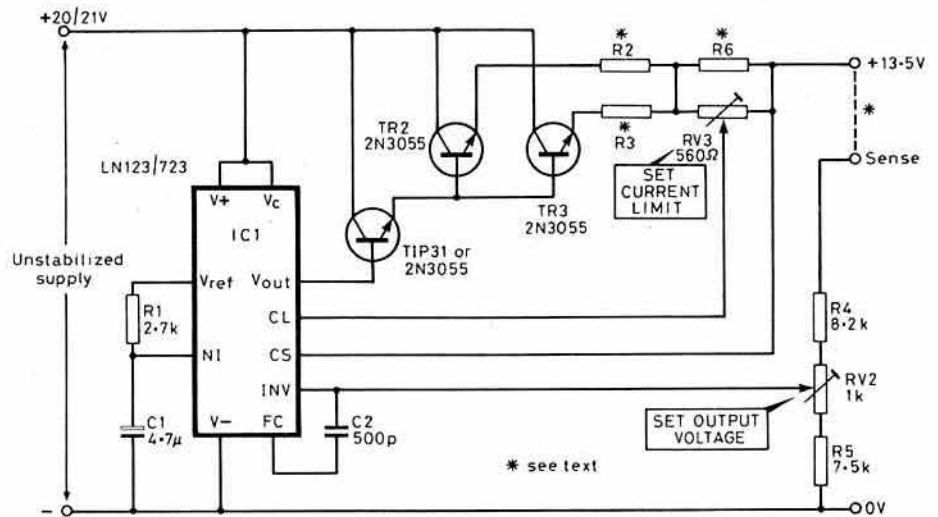


Fig 12. Basic psu using a power transistor as a current amplifier

CORRECTION

In Part 1, on page 490, column 1, final paragraph, the first line should read: Incidentally "Test turns used/ measured voltage" gives what is known as. . .

Fig 14. Complete stabilizer circuit with variable current limit but less over-voltage protection



will be adjusted by IC1 to offset the voltage drop in the supply lines between the psu and the load. If more output current is required, further 2N3055s may be connected in parallel with TR2 and TR3, with a stabilizing resistor in series with *each* emitter. Four 2N3055s will produce an output current of up to 20A; remember that the transistors will need some hefty heatsinks. Note that TR1 need not be a 2N3055 and could be of much lower rating, eg TIP31. Also, TR1 will only require a modest heatsink.

to IC1 to be adjusted to give a moderately variable limiting value. Note that if you are making a psu to give 20A you cannot expect to make it limit at 1A, because this would require a value of 0.55Ω for R6 and if the full output current of 20A was drawn there would be a voltage drop of 11V across R6!

Over-voltage

If the psu shown in Fig 14 is to be used with sensitive equipment that is critical of its supply voltage, then some form of overvoltage protection is necessary. If one of the 2N3055s should become short-circuit (emitter to collector) then the equipment would receive around 20-25V which would probably despatch most rigs. The simplest protection is of the "crowbar" type. A fuse connected in the line from the reservoir capacitor is blown by means of an scr connected across the *unstabilized* supply on the opposite side of the fuse remote from the reservoir capacitor.

IC2 is a custom-built crowbar device costing about £1 and is very effective. Radiospares RS3423 is one device easily obtainable. Many component retailers supply Radiospares components, but if difficulty in obtaining this item is experienced then the MC3423 PI is a direct equivalent. Fig 16 shows a suitable circuit. The scr is fired by a pulse from IC2 when the voltage at the output of the psu rises above the level set by the preset control RV4. Resistors R7 and R8 protect the scr which becomes a very low resistance and can pass hundreds of amps when it discharges the large reservoir capacitor. The value of these resistors depend on the designed output current and output voltage. For supplies at 13.5V, R8 should be 15Ω and R7 given by $20/4 \times \text{rating of the fuse}$; eg for a 20A psu, the fuse rating could be 13A and $R7 = 20/52$ about 0.5Ω. The choice of a 13A fuse for a 20A supply is quite deliberate. It must be remembered that 13A is the current that it can carry continuously and almost indefinitely. A current of twice the rating will not cause the fuse to blow, it needs just about 2.5 times the rating to do that. A 13A fuse causes a lower overload when the scr fires. C3 gives a small delay in firing the scr so that it is not operated by short duration pulses that can occur in the mains and that are not filtered out by the reservoir capacitor etc. A value of 10nF gives a delay of 0.1ms. □

I hope that some of these suggestions will be of help to constructors who, like myself, try to build things for less than nothing! Do have a go, it's not nearly so difficult as it sounds.
GW4HWR

Current limit

This is provided by R6, which applies a voltage between CL and CS of IC1. When this voltage reaches 0.55V the output at Vout is progressively reduced so that the output current cannot increase beyond the fixed limit. The value of R6 may be calculated by dividing 0.55V by the current at which limiting is to take place; eg at 20A, $R6 = 0.55/20 = 0.0275\Omega$. Note that if a short-circuit occurs across the output, the current will rise to 20A and remain at that value until the short is removed. It is therefore necessary to be sure that the heatsinks can maintain a sufficiently low temperature to prevent damage to the transistors.

R6 can be made up as described for the 0.1Ω ballast resistors, but using more strands depending on the current to be carried. The exact value of R6 can be found experimentally by starting with a value that is too high and progressively reducing it until the correct value of current is reached. Alternatively the arrangement as shown in Fig 14 may be used where R6 is rather bigger than the calculated value and RV3 allows the voltage applied

Fig 15. The pin connections

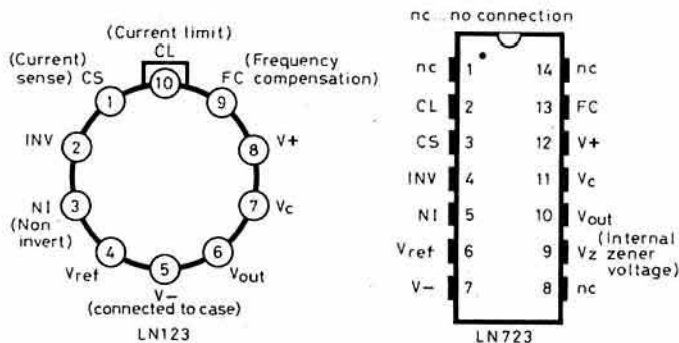


Fig 16. The extra circuitry needed to provide protection against excessive output voltage. To set the "trip volts" control, disconnect R8 from the gate of SCR1 and connect a voltmeter between the open end of R8 and 0V. Adjust RV4 until the meter reads high, then back it off until it reads low

